Recent advances in characterizing snow-forest interactions

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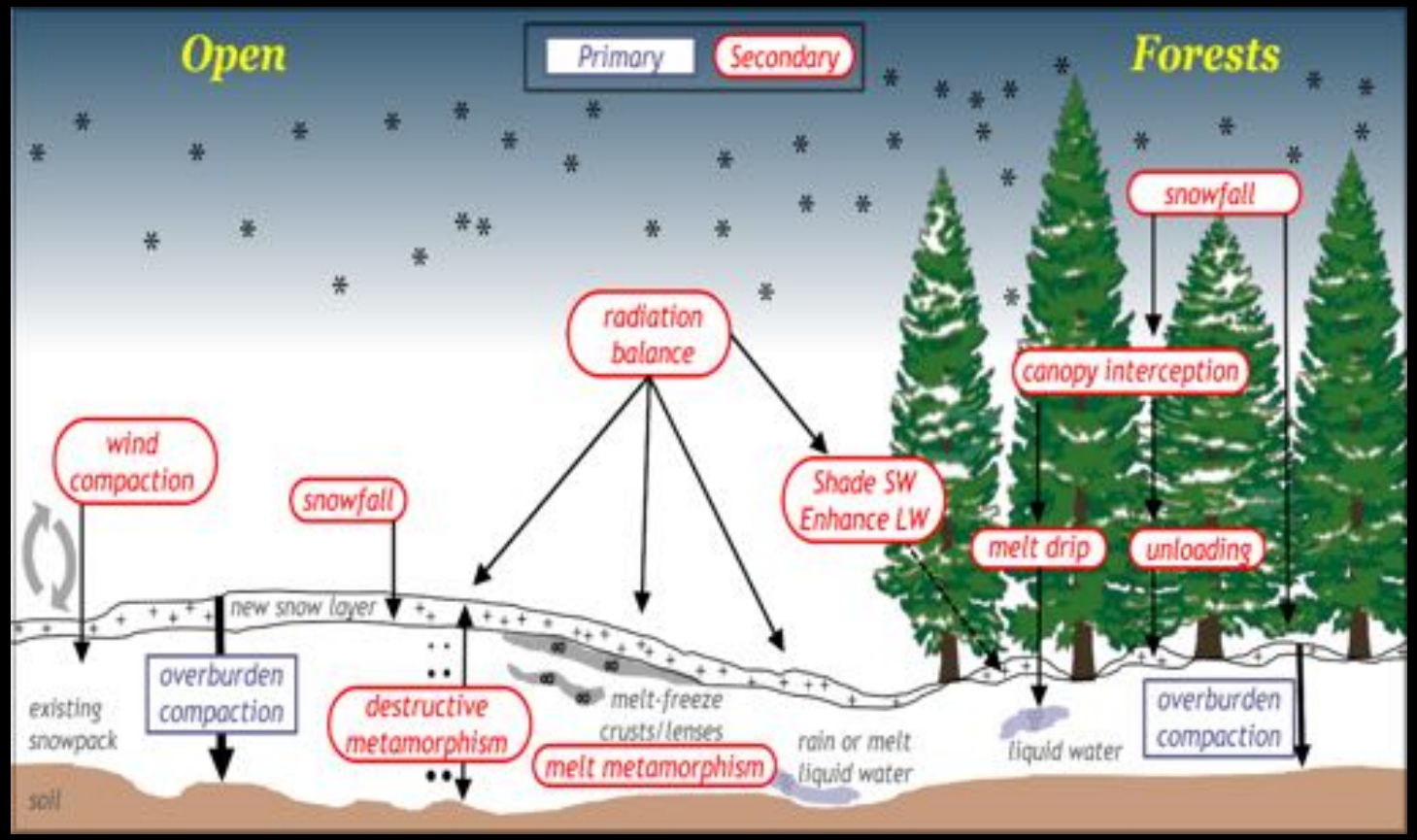
Snow/Forest Interactions



- Canopy snow interception is difficult to measure and model
- Forests reduce sub-canopy turbulent fluxes (latent & sensible) but canopy sublimation rates are high
- Forest litter reduces snow albedo but forests reduce incoming SW radiation
- Forests emit longwave radiation
- Energy balance differences affect snowpack evolution

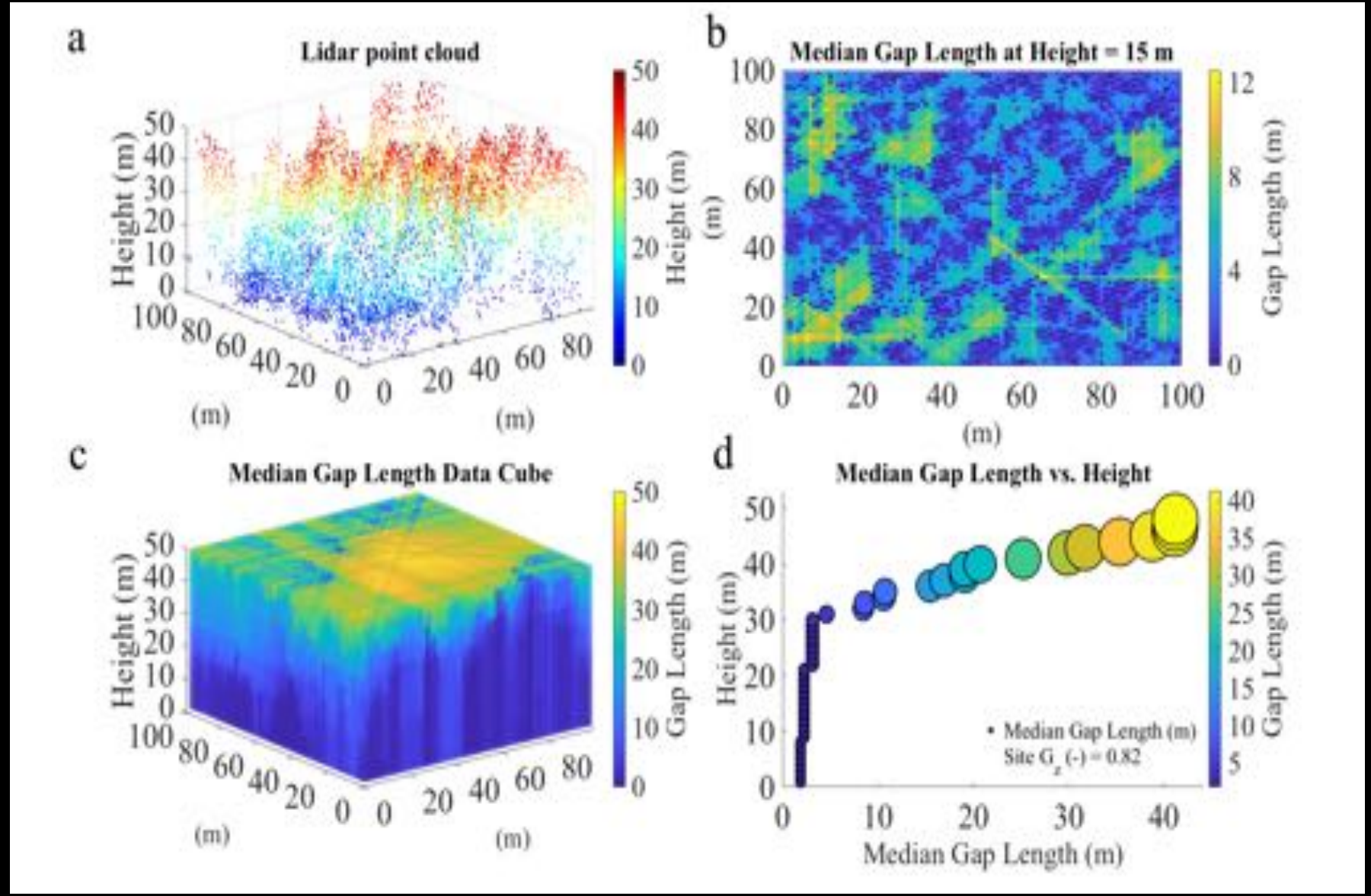
Source – Mark Raleigh

Forest canopy interception depends on gap size and shape

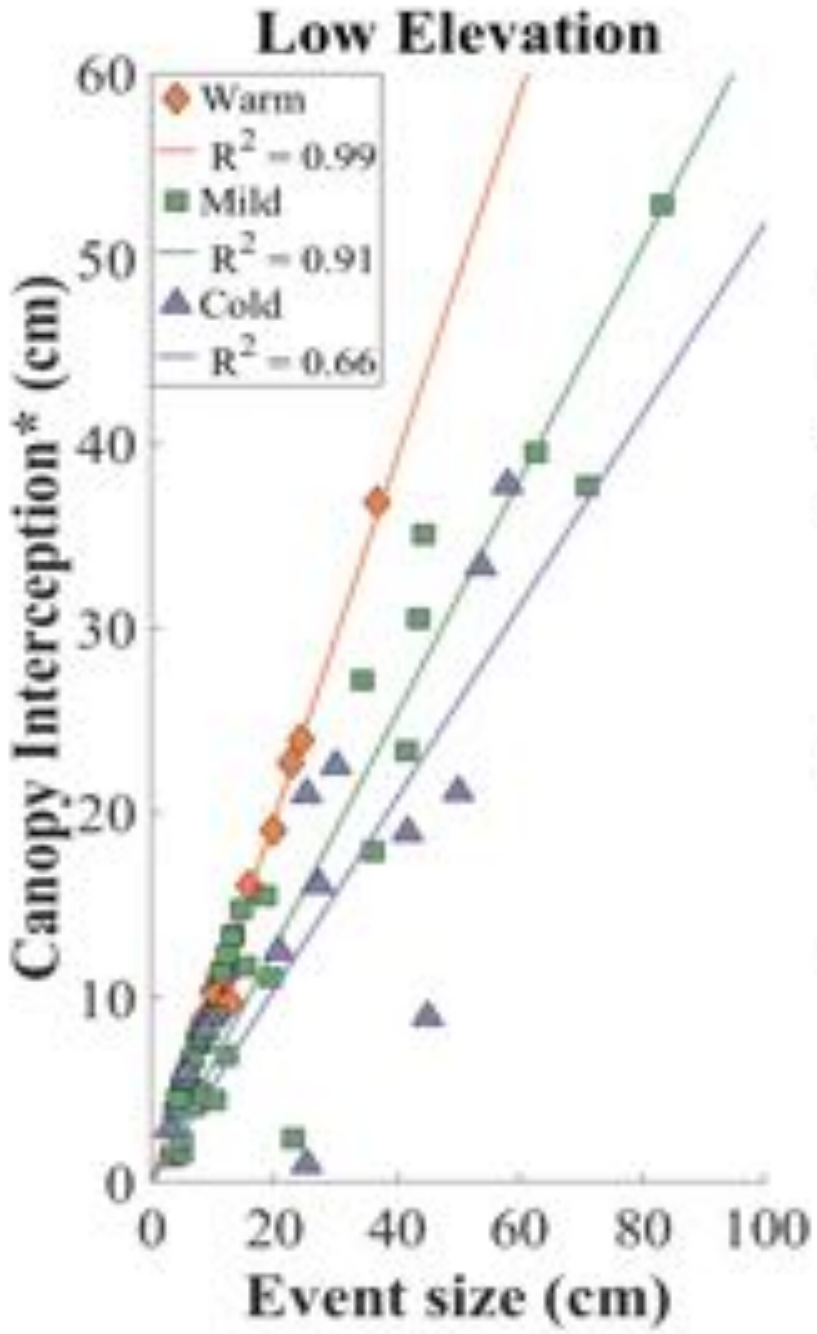
3D Gap Size:
is calculated as

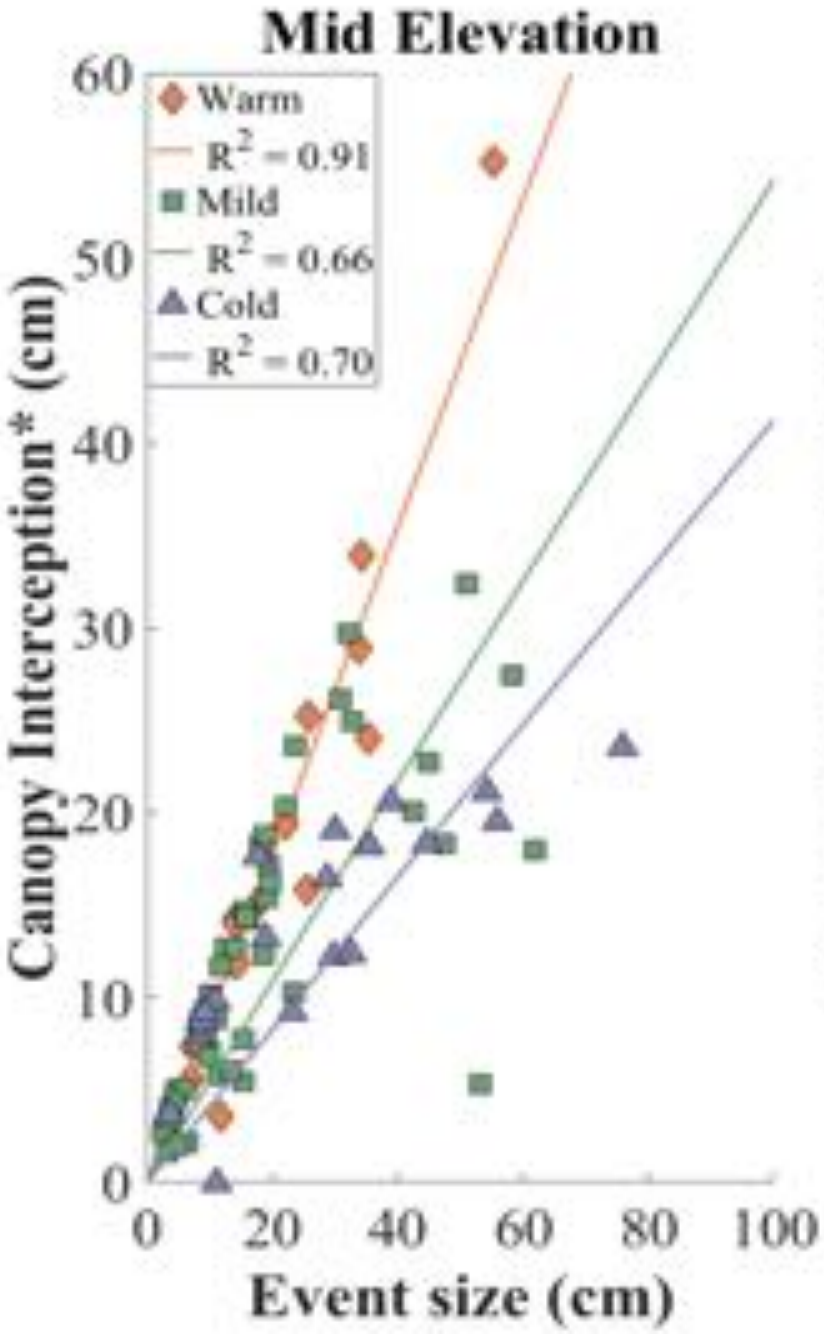
$$G_z = \frac{\Delta G}{\Delta z}$$

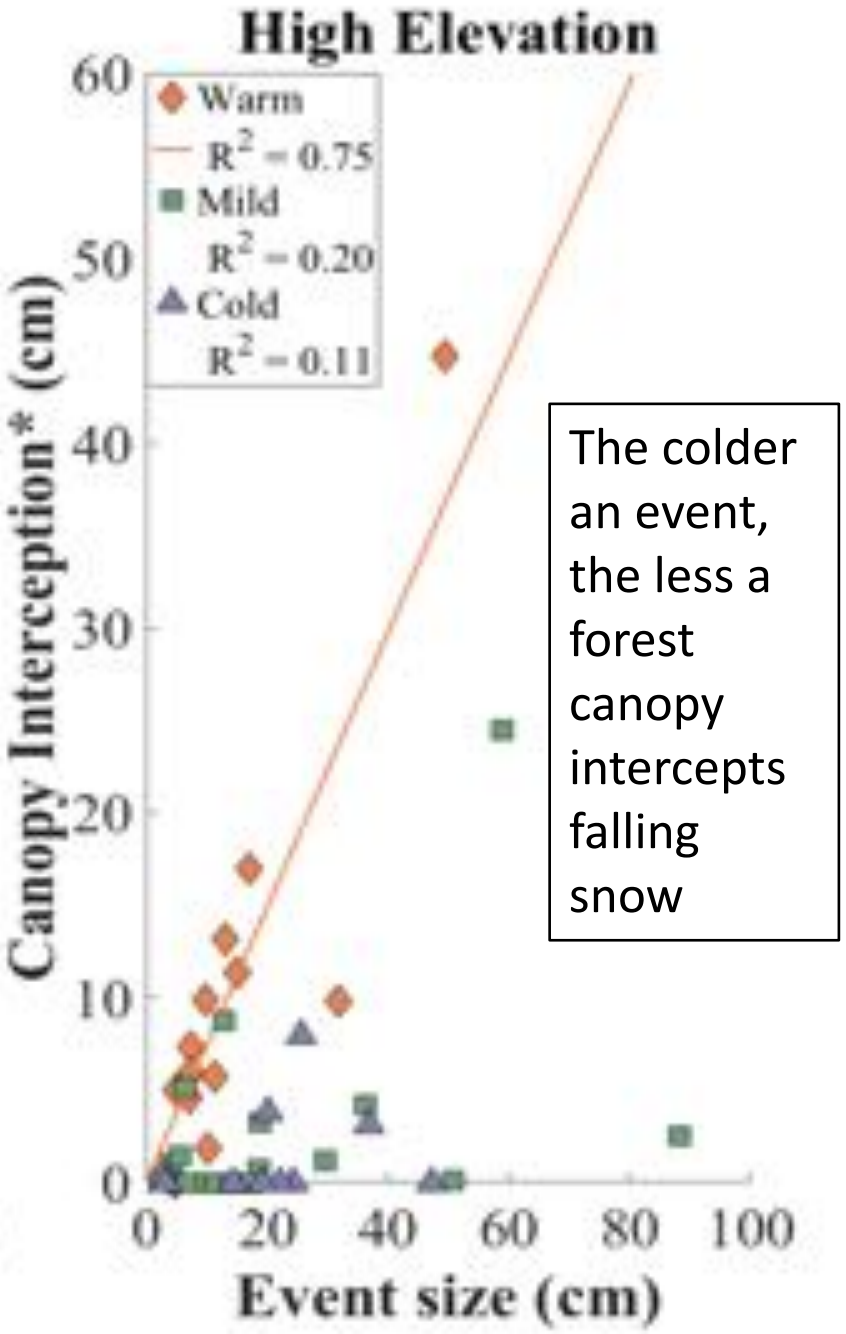
where G is the median gap length (m) of the 8 directions around a point along within a horizontal slice and z is the elevation above the ground surface (m)



Roth & Nolin, 2019 WRR







The colder an event, the less a forest canopy intercepts falling snow

(Roth & Nolin, 2019)

Roth parameter:

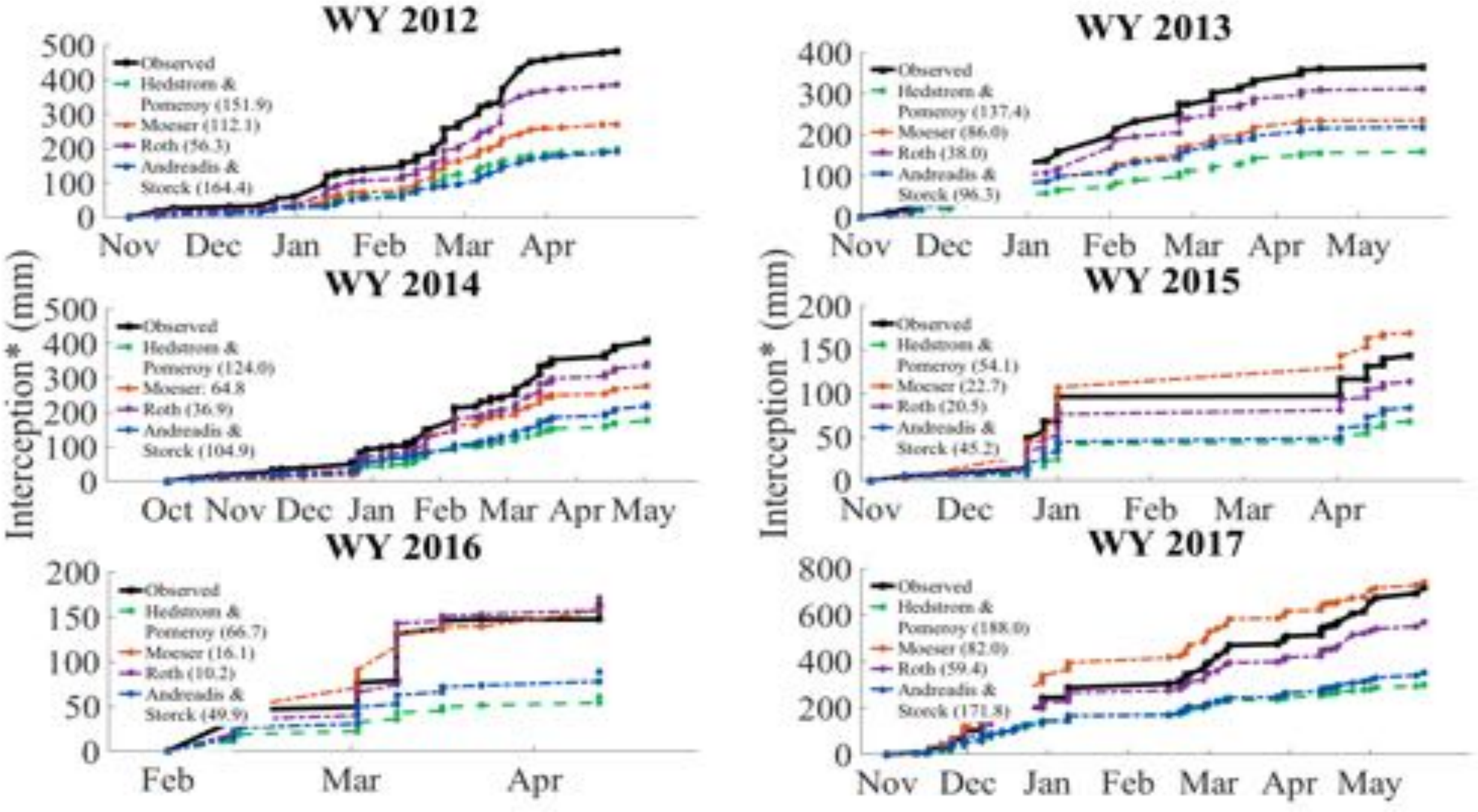
$$\xi = 0.04 * T_{air} * G_z + 1.56$$

Event canopy interception* is estimated by a power law relationship between event snowfall (P; mm) and the Roth parameter:

$$I_{Roth} = P^{\xi}$$

Low complexity forests decrease interception capacity from the outset, whereas a highly complex forest increases interception potential and leads to a nonlinear increase in temperature-based canopy interception due to more surface area able to intercept falling snow

Forest structure sets the boundary condition of the potential to intercept, while event size and T_{air} determines the rate or amount of interception



(Roth & Nolin, 2019)

Canopy Interception*

Canopy interception efficiency (CIE) depends on forest structure, snowfall temperature, and snowfall amount

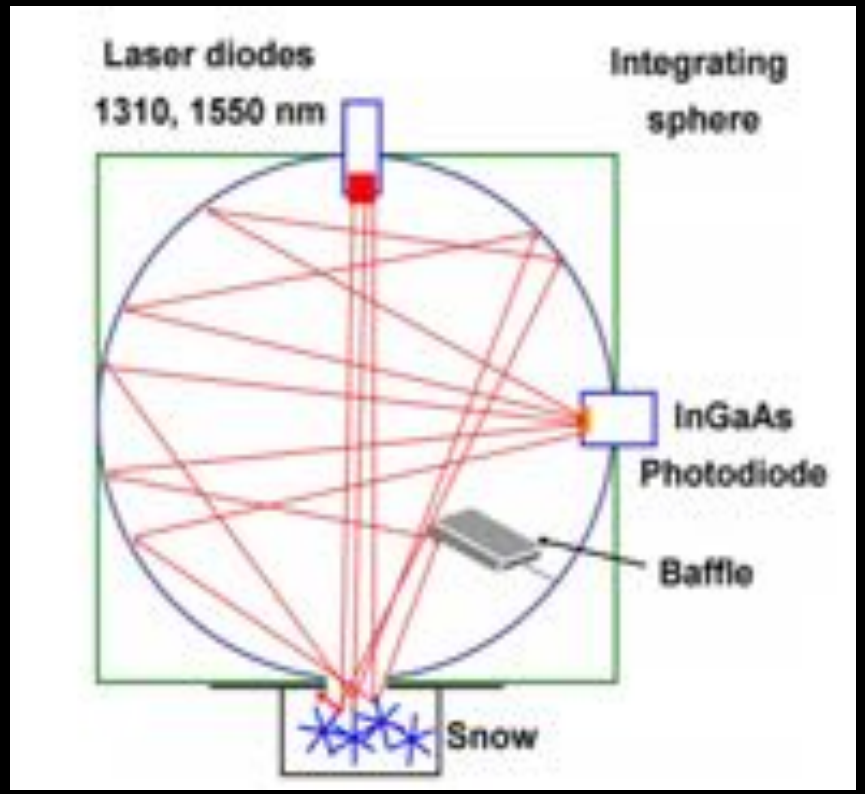
- Dense forest with small gaps will intercept more snow than open areas
- Interception is greater for warm snowfall than cold snowfall events
- Interception is greater for high snowfall events

Grain Size and Snow Specific Surface Area (SSA)

Optical grain size ($d_{\mathbf{opt}}$): optically equivalent sphere that produces the same reflectance properties as the snowpack; characterized by surface-to-volume ratio.

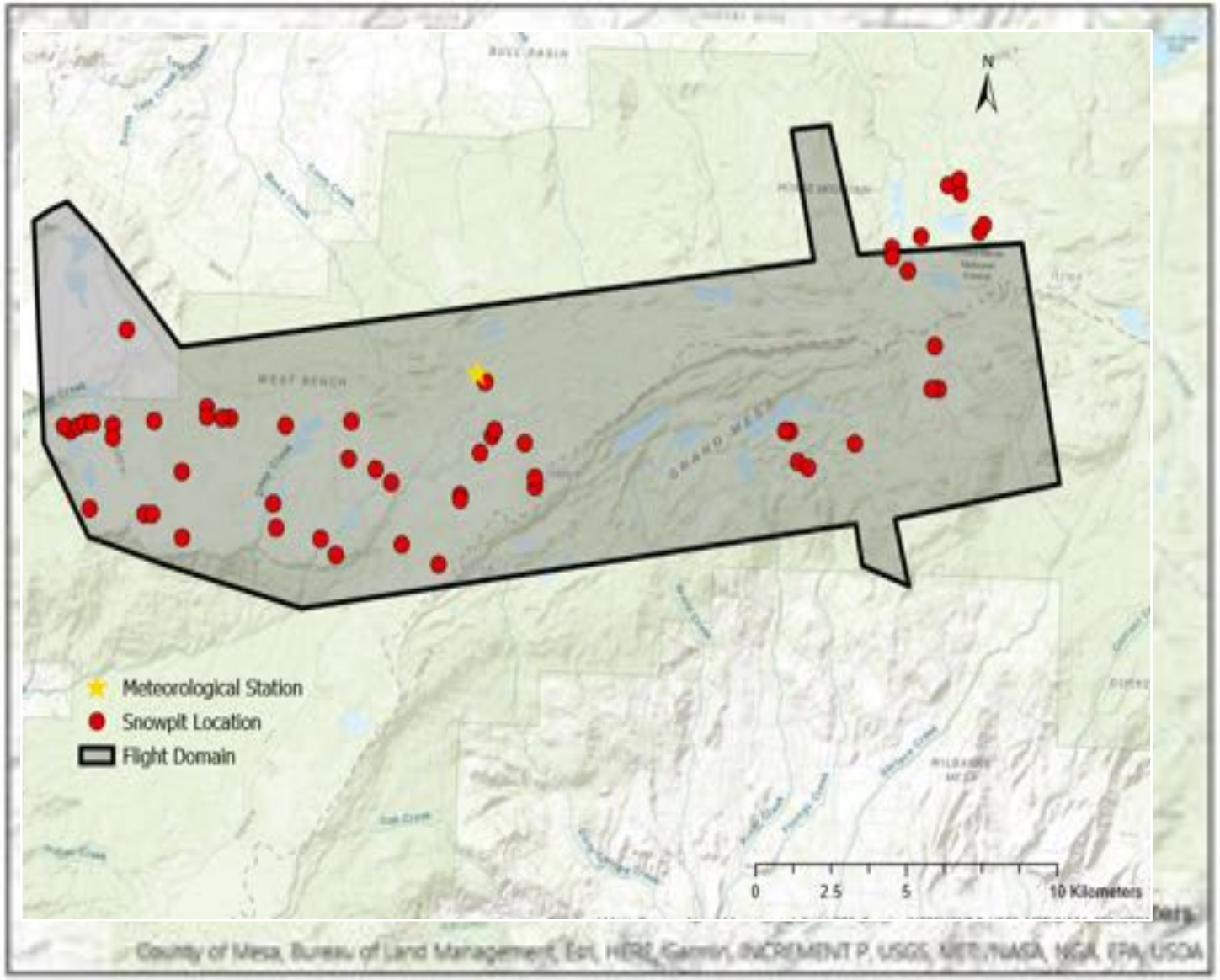
Specific Surface Area (SSA): derived from d_{opt} and is a geometrical characteristic of porous sintered materials, such as snow, and is related to chemical, physical, and electromagnetic properties of the medium

$$SSA = \frac{6}{d_{\mathrm{opt}} * 917}$$



SnowEx 2017
Grand Mesa, Colorado

JPL Airborne Snow Observatory
Lidar acquisition extent
Snow pits and met station

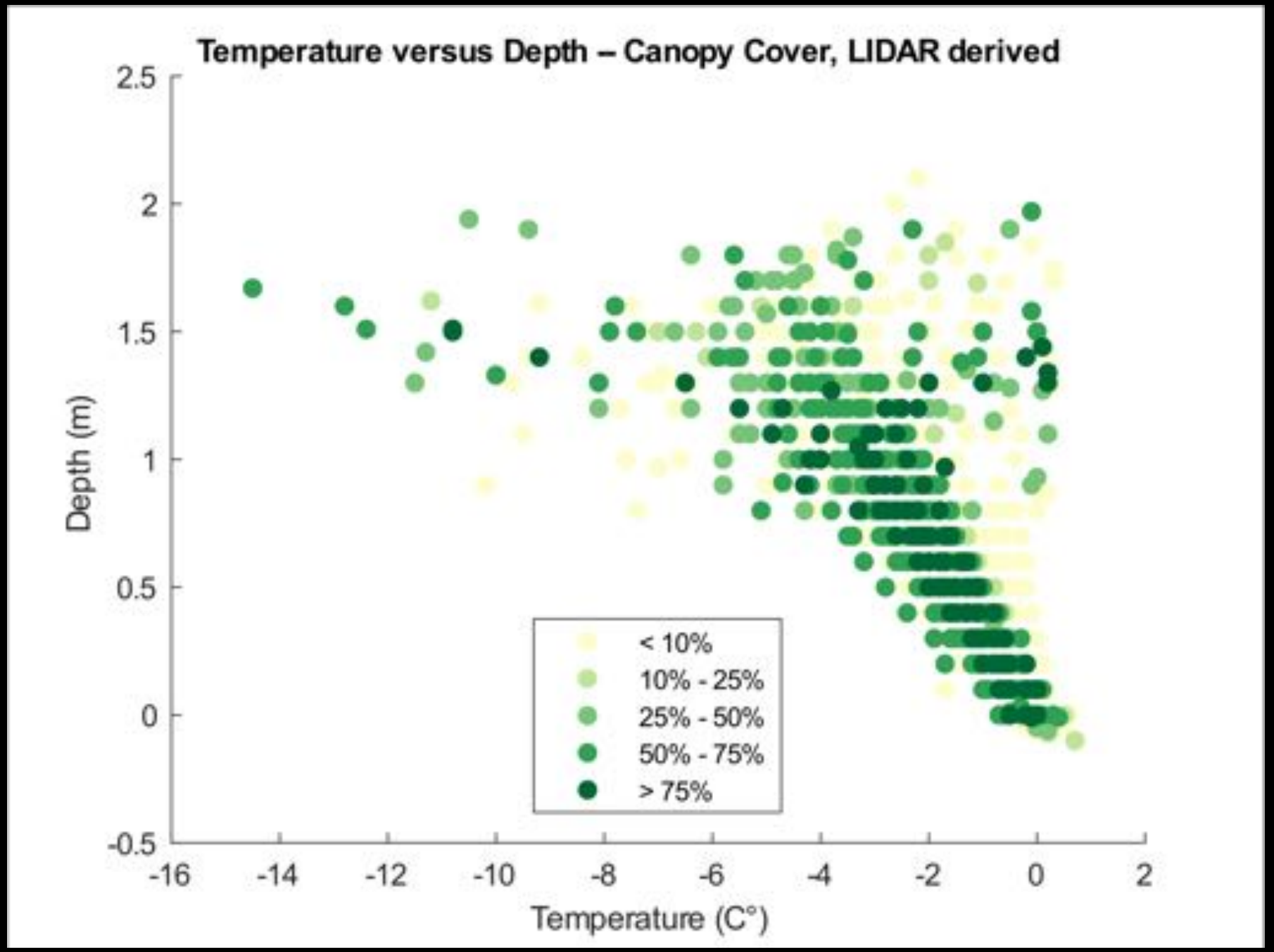


Lidar-derived forest density (shown here as sky-view factor)

SnowEx, JPL Airborne Snow Observatory

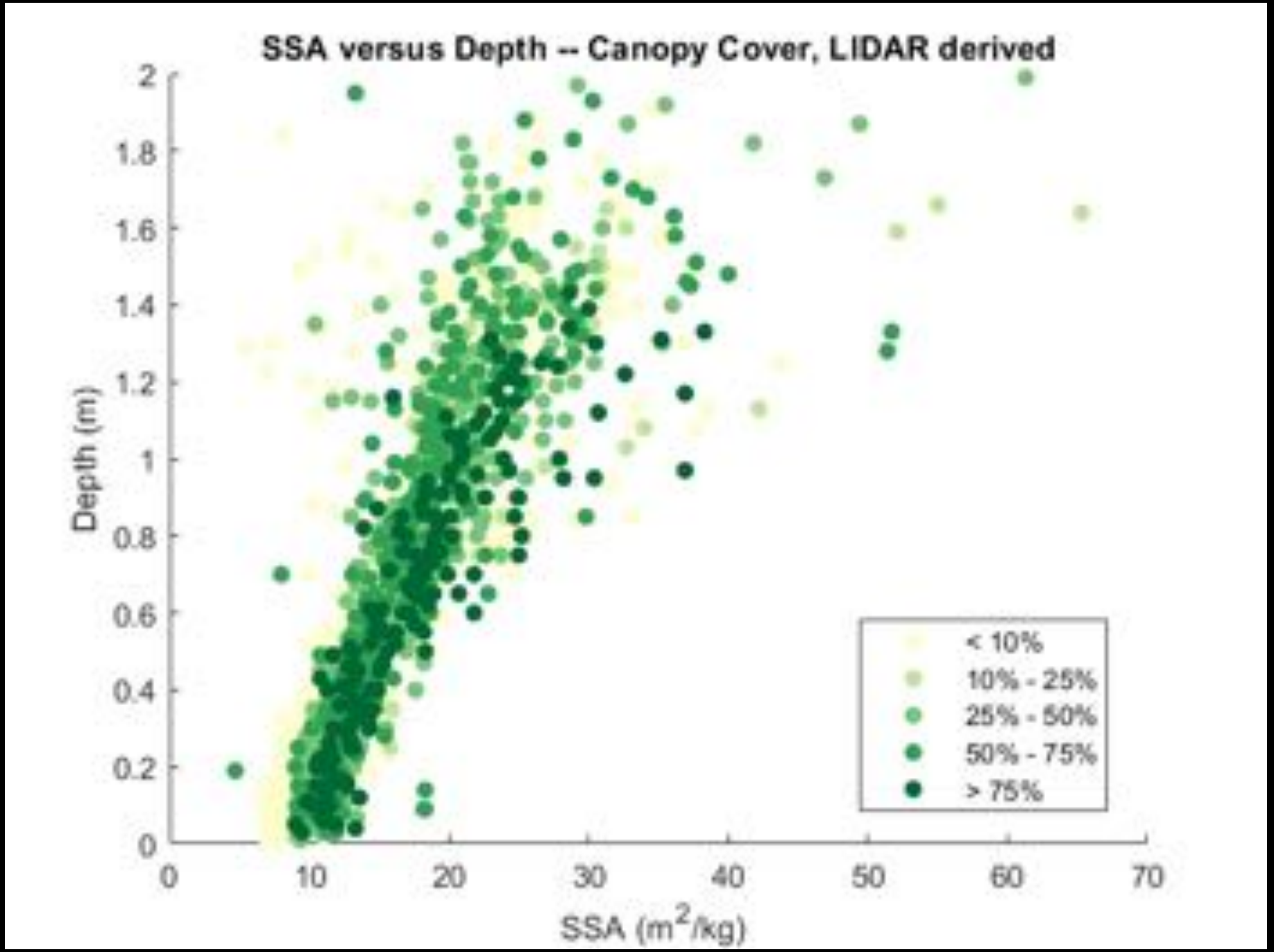
Observational Results:

Forested sites tend to be colder than open sites, with slightly larger dT/dz than open sites

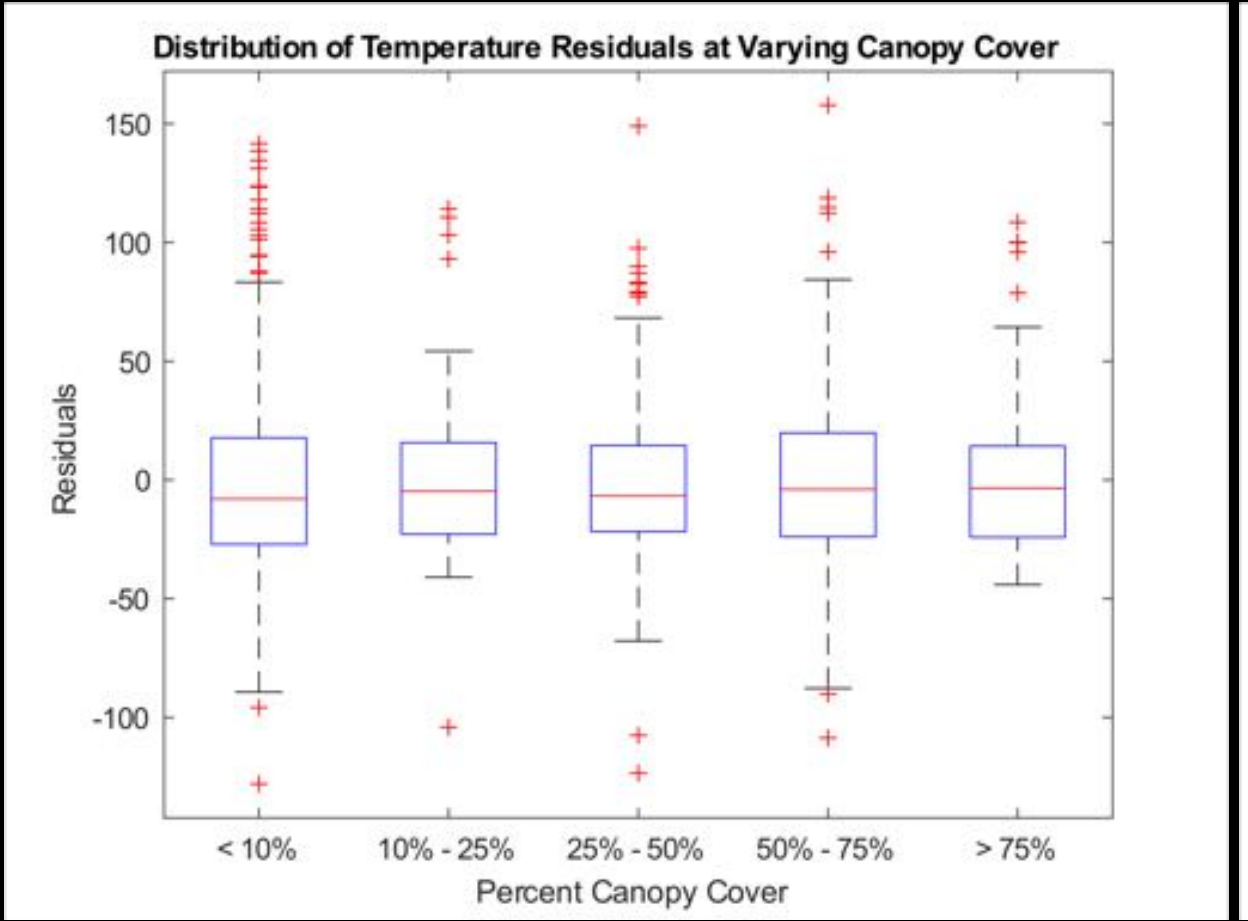


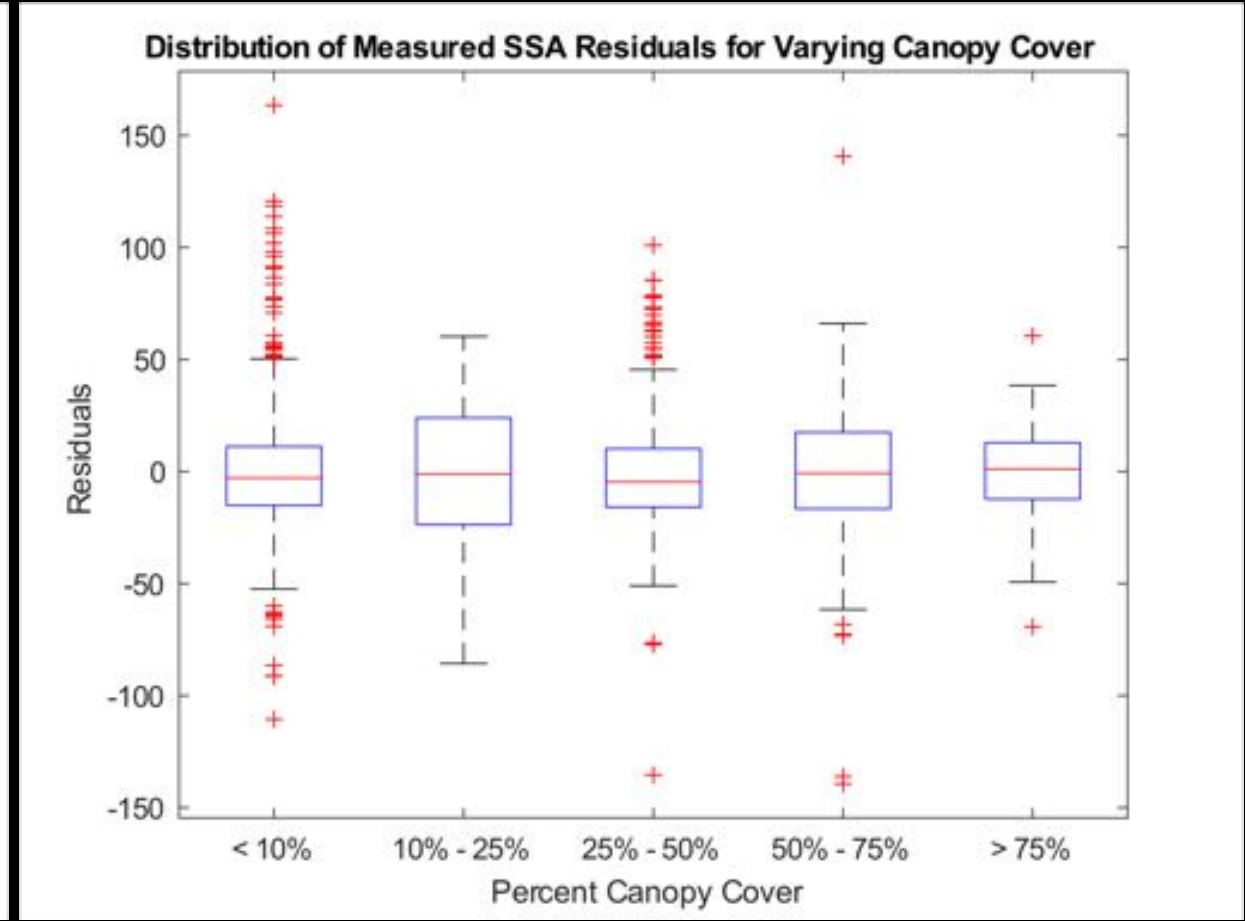
Observational Results:

SSA values are not significantly different between forested and open sites



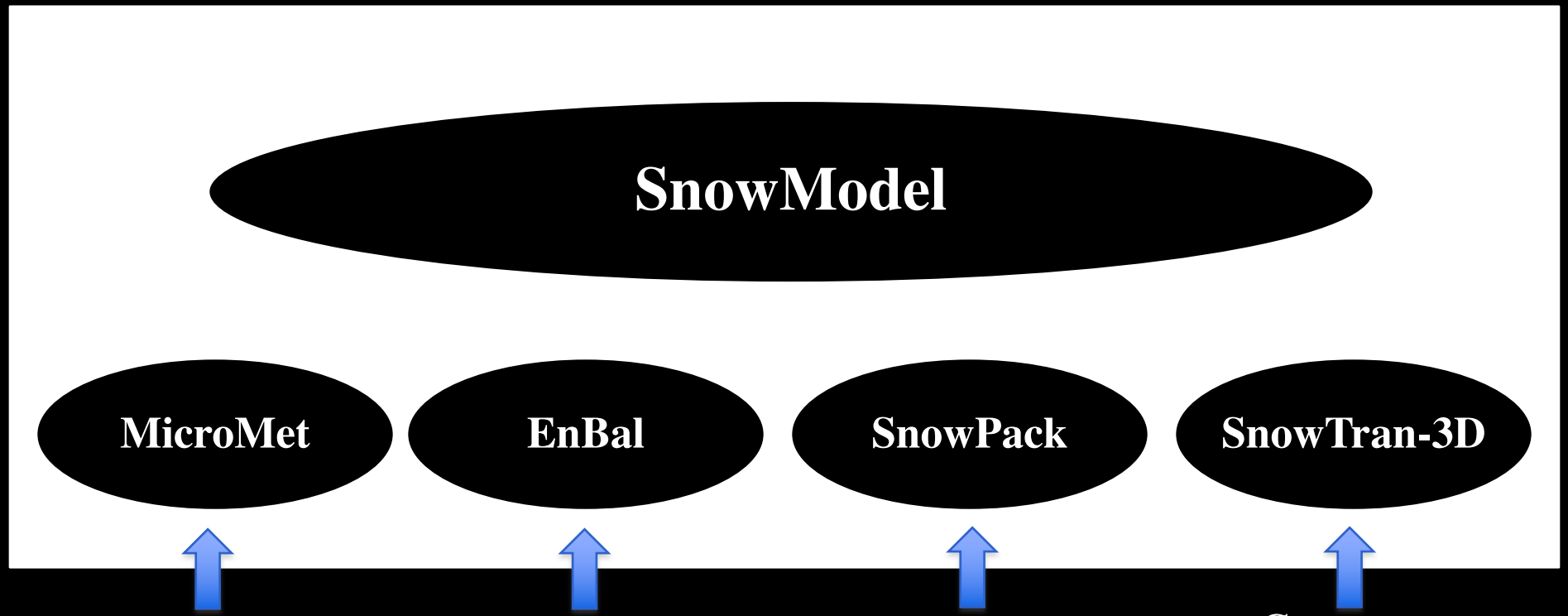
Observational Results:
Residuals have greater spread for open sites





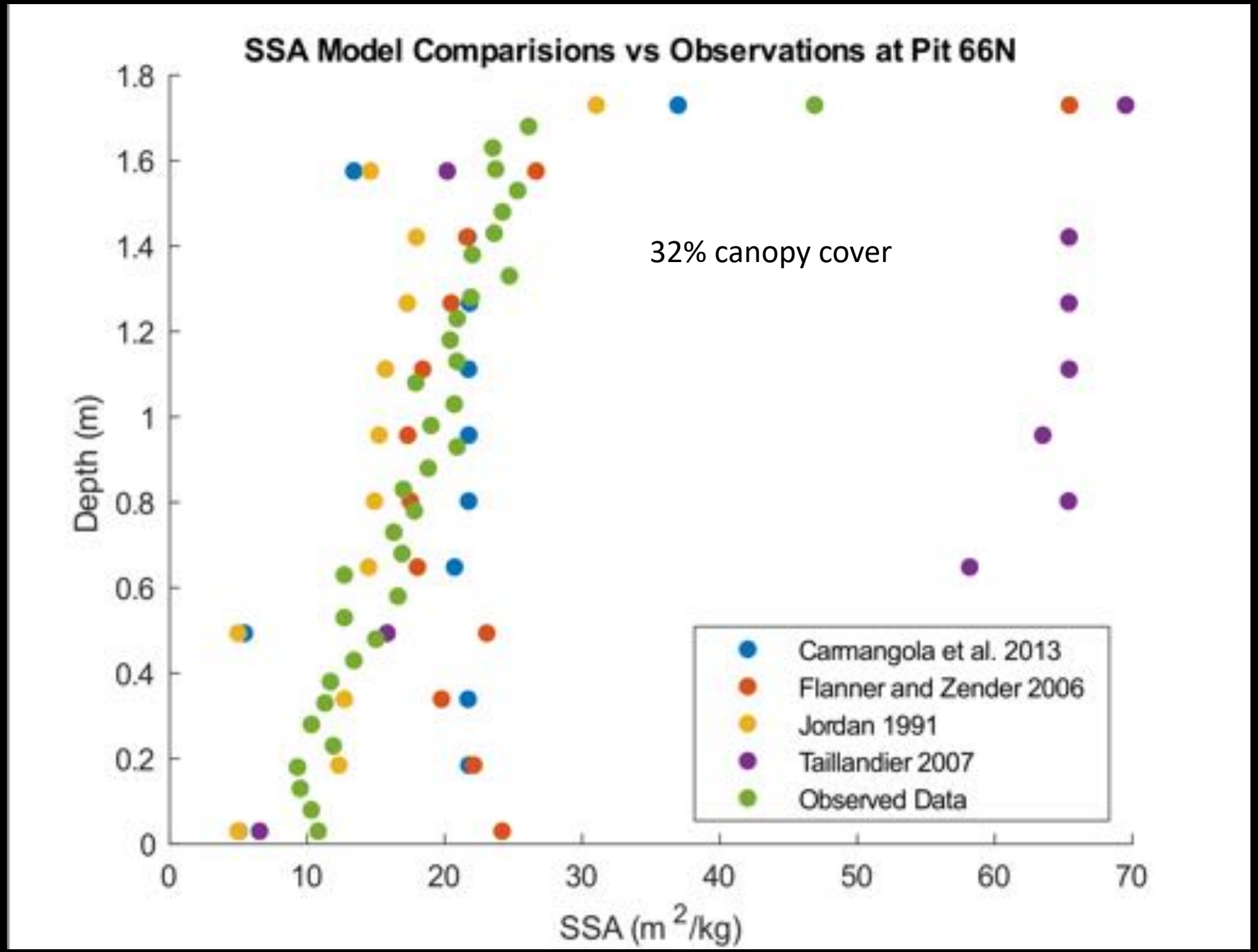
Process	Forest	Open
Incoming SW radiation	Lower in forest	Greater in open
Incoming LW radiation	Greater in forest, due to canopy emission	Lower than in forest, no canopy emission
Snow accumulation	Less accumulation due to interception	No interception, full accumulation
Turbulent fluxes	Less exposure to turbulent fluxes due to protection from canopy	Subject to wind scour, wind compaction, and destruction of snow grains due to grain to grain collision
Albedo	Forest litter collects on the surface of the snowpack, decreasing albedo	Forest-adjacent areas may accumulate particulates
Temperature (varies by site)	Temperature is greater in the forest than the open from ~ 5pm – 8am by ~1.3 °C	Temperature is greater in the open than the forest from ~ 8am – 5pm by ~0.6 °C

SnowModel (Liston and Elder, 2006; with modifications) computes snow properties across the model domain



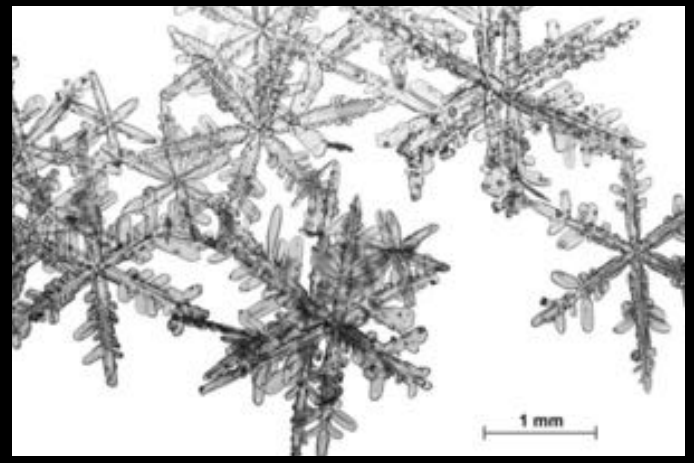
Assessed 4 snow grain evolution algorithms:

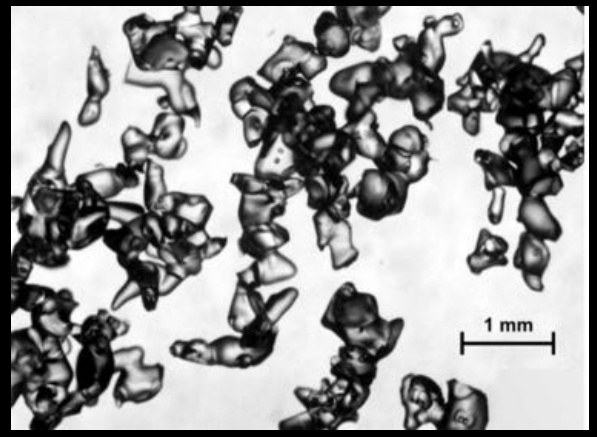
1. SNTHERM (Jordan, 1991)
   Physically-based, 1-D, based on Colbeck
2. Crocus (Carmagnola et al. 2014) – C13
   Physically-based, used for avalanche prediction
3. Flanner and Zender (2006) – F06
   Empirical model, used in Community Land Model for albedo estimation
4. Taillandier et al. (2007) – T07
   Empirical model, used to estimate SSA and gas exchange in the snowpack

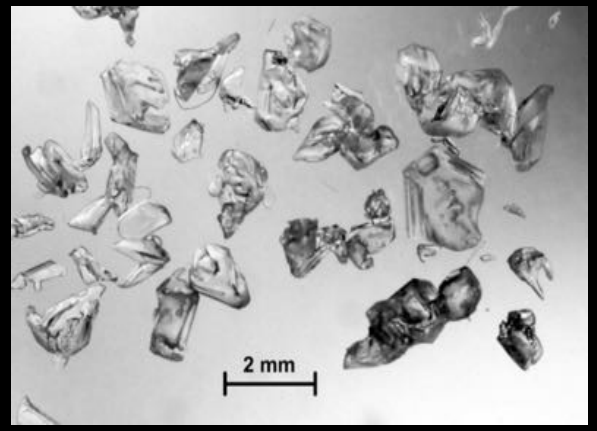


Physically-based models have the closest agreement with observations

Example comparison of SSA profile for a single day







Snow Grain Evolution

No significant grain size differences between forest and open areas

- Forest energy balance is less variable than open areas
- Physically-based models are more accurate than empirical models
- Models need multiple layers to adequately represent snowpack processes

Sagehen Winter Experiment

Locations of eddy flux, snow, and energy balance stations

Legend

Station number

S1

S2

S3

S4

S5

N

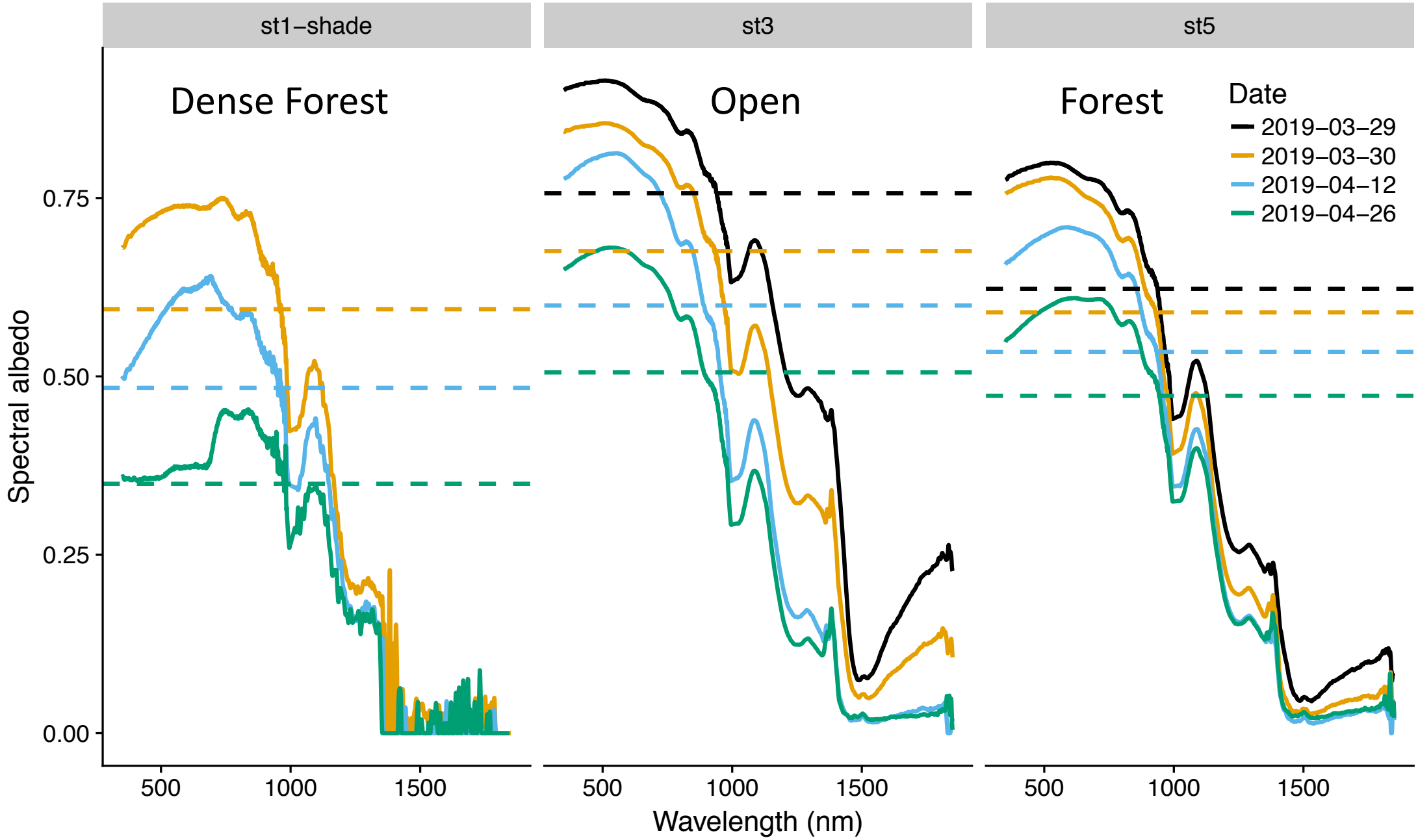
200 m

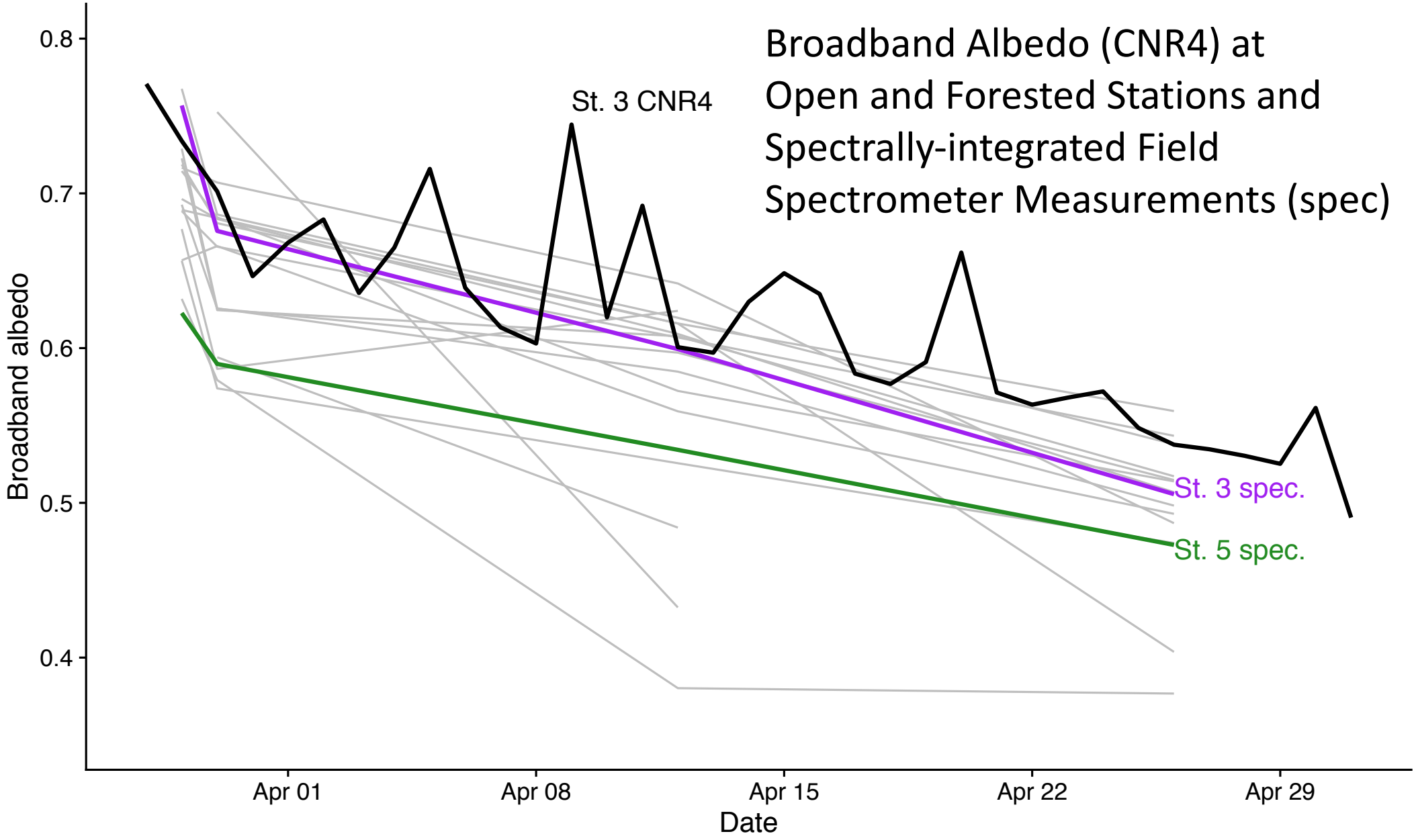
Google Earth

© 2018 Google

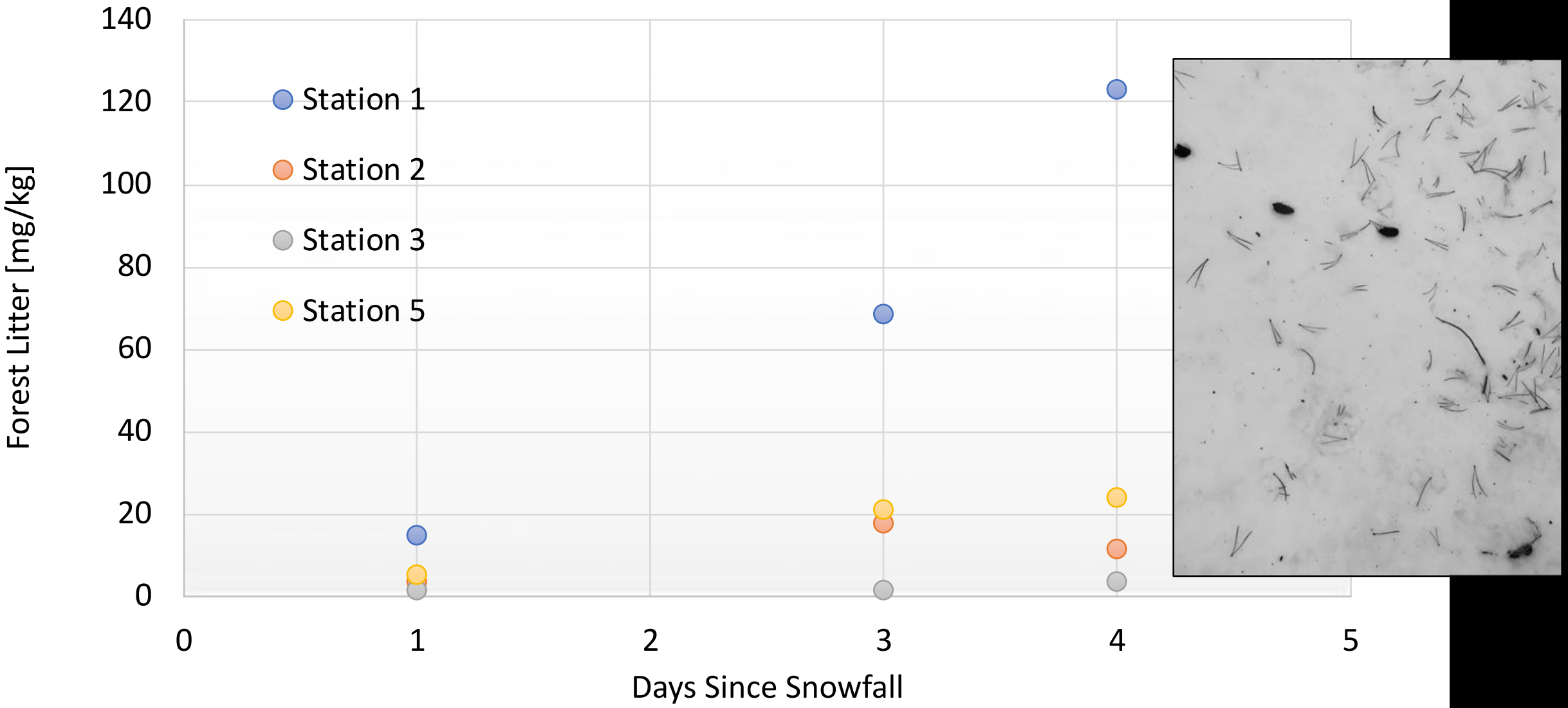
Multi-date field spectrometer measurements of Vis/NIR spectral albedo along a transect from forested to open sites

Snow samples collected and analyzed for forest litter, dust, black carbon particles


st1–shade
st3
st5
Dense Forest
Open
Forest
Date
2019–03–29
2019–03–30
2019–04–12
2019–04–26
Spectral albedo
0.75
0.50
0.25
0.00
500
1000
1500
Wavelength (nm)


Broadband Albedo (CNR4) at
Open and Forested Stations and
Spectrally-integrated Field
Spectrometer Measurements (spec)
St. 3 CNR4
St. 3 spec.
St. 5 spec.
Broadband albedo
0.8
0.7
0.6
0.5
0.4
Apr 01
Apr 08
Apr 15
Apr 22
Apr 29
Date

Forest Litter vs. Days since Last Snowfall



Snow Albedo in Forested Areas

Snow albedo in forests is REALLY different from open areas

- Spectral and broadband albedo values are affected by forest litter and snow grain size
- Some interesting questions about black carbon and dust

Thank You.
Questions?